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Studies on centipede communities (Chilopoda) from three habitats in Toledo Province, Spain*

by

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ABSTRACT

The current work presents a study of the centipedes captured in three habitats of Toledo Province, Spain. These habitats correspond to a riverside, a well preserved green oak forest, and a rural field degraded by anthropogenic action. Sampling was performed using both direct capture and Berlese extraction from soil cores. In total, 12 different centipede species were collected. Analyses of frequency, abundance and density were performed, and species richness and indices of diversity, uniformity and dominance calculated. The results obtained show the highest values of mean density and average species richness (eight species) corresponding to the riverside fauna. The number of species taken in the rural field habitat (seven) was slightly lower, and so was the average species richness. The green oak forest supported the poorest chilopod fauna (three species), as well as the lowest average species richness. There was no statistically significant difference between the monthly densities for all species in the three habitats sampled, and this could be due to the large monthly variation. Diversity and maximum diversity indices showed relatively low values in the three areas regardless of the sampling method applied. Statistical analysis revealed significant differences only between the monthly diversity values of the riverside and rural populations against the green oak forest one. A comparison of results obtained from direct capture and from soil sampling and Berlese extraction, showed that the monthly density values of all Chilopoda were significantly higher for soil samples than those derived from direct capture.

INTRODUCTION

The centipede fauna of central Spain, in particular Toledo Province, is still poorly known (Brölemann 1930; Attems 1927; Serra 1980). Based on a preliminary sampling effort across the entire Toledo Province (García Ruiz 1997), a study was designed to survey three of the most characteristic habitats of the area. These three habitats correspond to a riverside, a rural field, and a well-preserved green oak forest site at Toledo, Ontígola and La Morra, respectively.

Data obtained in this study provide important information on the faunal composition, phenology and structure of the centipede communities of all three habitats. They also allow for a comparison to be made between the results obtained using two completely different sampling techniques.

STUDY AREAS

The study areas are located in Toledo Province, Community of Castilla la Mancha, Spain. They are subjected to a mesomediterranean climate while their vegetation, according to Monje (1988), is that of a Luso-Extremadurense region.

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*Note that all Tables are presented at the end of the paper.

The first study plot corresponded to a riverside of Tajo River, located within the municipality of Toledo, at an altitude of 500 m (UTM 30SVK1213). It is characterised by a high degree of humidity due to the water supply of the river. The vegetation is characterised by the presence of rushes (*Juncus* sp. and *Scirpus* sp.), reed and reedmace (*Tyhpa* sp.).

The second study area corresponded to a rural landscape located in the municipality of Ontígola, at an altitude of 740 m (UTM 30TVK5128), with a vegetation of nitrophilic communities including *Aethusa cynapium* L., *Cirsium palustre* L., *Onopordum acanthium* L. and *Hordeum murinum* L.

The third habitat investigated corresponded to a green oak forest located in the Toledo Mountains, Los Yebenes-La Morra, at an altitude of 800 m (UTM 30SVJ2864), with vegetation formed mainly by *Quercus coccifera* L.

METHODS

Sampling was performed on a monthly basis between April 1993 and April 1994. Table 1 shows the sampling schedule.

In each area, a plot of 50 x 50 m was delimited. This plot was divided into five rectangles of 10 x 50 m and a 2 m diameter circle was randomly chosen in each of them. The circle was sampled through direct capture and also using an edaphic probe of 20 cm in diameter to obtain a soil sample from which Chilopoda were later extracted by means of Berlese funnels (Ascaso 1986; Andrés 1990). In this way, the total area sampled on each plot per month was 15.7 m^2 through direct capture, and 0.16 m^2 using soil samples. A paired t-test was used to check whether significant differences existed between monthly densities in each area, depending on the sampling method.

The relative abundance, frequency (percentage of samples in which each species was captured) and population densities with Pearson's coefficient of variation, were calculated for each species. Chilopoda communities were characterised by calculating their species richness, Shannon's diversity and uniformity indices.

RESULTS

Faunistic composition

Twelve different species of Chilopoda were collected in total. According to Brolemann (1930), they represented the following biogeographical groups:

- European: *Lithobius borealis* Meinert, 1872, *Lithobius lusitanus* Verhoeff, 1925 and *Geophilus insculptus* Attems, 1895.
- Mediterranean: *Dignathodon microcephalum* (Lucas, 1846), *Scolopendra canidens oraniensis* (Lucas, 1846), *Scolopendra cingulata* Latreille, 1829, *Cryptops trisulcatus* (Brolemann, 1902), and *Lithobius castaneus* Newport, 1844.
- Palaearctic: *Geophilus carpophagus* Leach, 1814.
- Holarctic: *Pachymerium ferrugineum* (C. Koch, 1835).
- Atlantic: *Haplophilus dimidiatus* (Meinert, 1870).
- Cosmopolitan: *Scutigera coleoptrata* (Linné, 1758).

Study of populations

The total number of specimens captured by soil sampling amounted to 306 individuals: 134 in the riverside, 98 in the rural field, and 74 in the green oak forest habitat. Using direct capture, 121 individuals were sampled: 53 in the riverside, 47 in the rural field, and 21 in the green oak forest habitat.

Tables 2–4 show the number of individuals of each species captured in each of the 13 edaphic samples. Tables 5–7 show the same data, but for material collected by direct capture.

Geophilomorpha appeared to be the most abundant centipede order in the riverside community, representing 37.31 % of the Chilopoda captured in soil samples, and 41.51 % of those taken by direct capture. Lithobiomorpha were slightly less abundant (35.07 % and 32.08 % respectively), followed by Scolopendromorpha (17.91 % and 20.75 % respectively). Scutigeromorpha showed the lowest relative abundance (9.70 % and 5.66 %, respectively) and represented the only order present in the riverside plot but absent from both other habitats.

Regarding the species caught in the riverside habitat, the relative abundance and capture frequencies depended on the sampling method used. Considering the soil samples, *L. lusitanus* was the most abundant and frequent species, followed by *S. cingulata* and *P. ferrugineum*. Considering the results obtained by direct capture, *S. cingulata*, *P. ferrugineum* and *L. castaneus* were the species showing the highest relative abundance and frequency values. All these species, along with S. *coleoptrata*, which only appeared in this plot, can be considered as the most representative species of the riverside habitat.

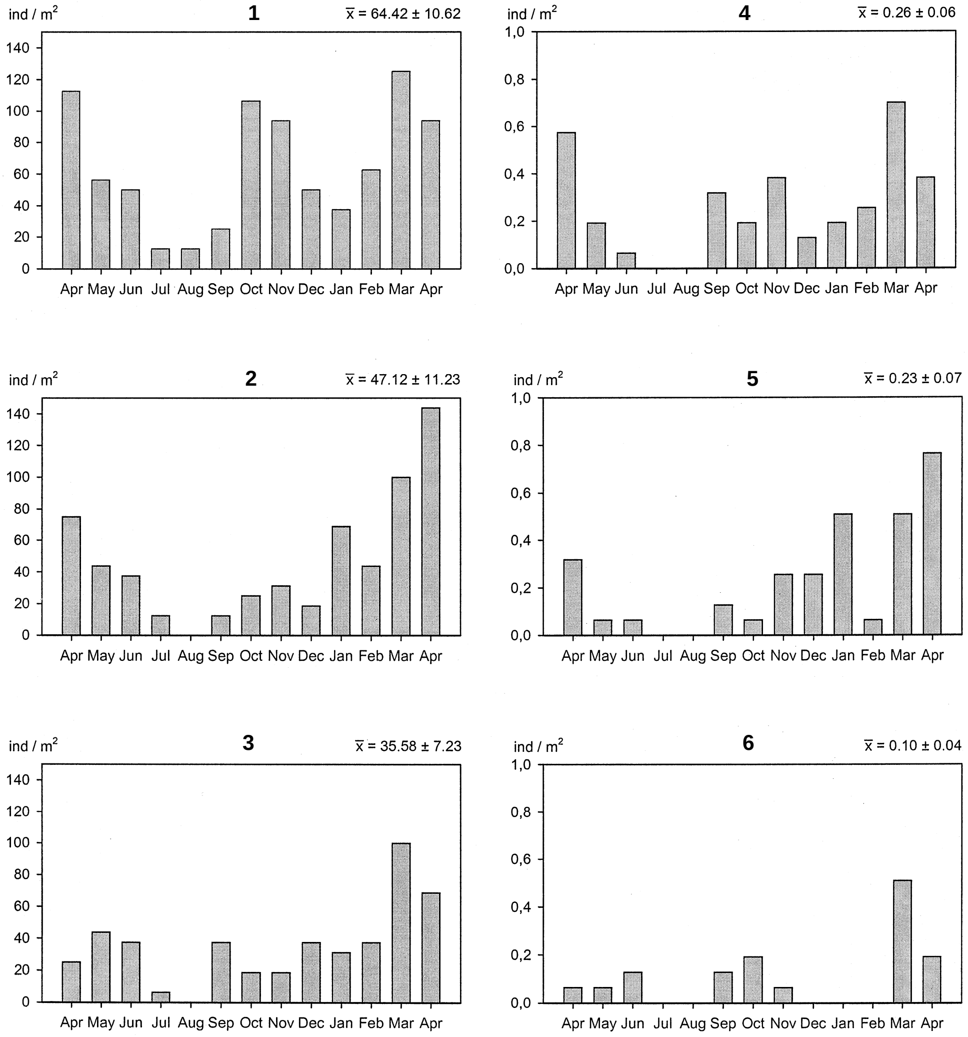
In the rural plot, Scolopendromorpha was the most abundant order (38.78 % and 46.81 % of Chilopoda taken by soil sampling and direct capture, respectively). The other two orders showed similar abundance percentages: 33.67 % and 23.40 % in the Lithobiomorpha, and 27.55 % and 29.79 % in the Geophilomorpha, respectively. The species which showed the highest abundance and frequency values using both sampling methods was *S. cingulata*. *Lithobius lusitanus* was dominant in the soil samples, while *H. dimidiatus* and *S. canidens oraniensis* were most abundant in the direct capture pool. Finally, the occurrence of *C. trisulcatus* in the rural field habitat is noteworthy, as this species fails to inhabit the other two areas.

The orders of Chilopoda in the green oak forest appeared to be represented in similar proportions to those in the rural field fauna. Scolopendromorpha accounted for 45.95 % and 42.86 %, Geophilomorpha for 29.73 % and 38.10 %, and Lithobiomorpha for 24.32 % and 19.05 % of the fauna respectively. Using both methods of sampling, *S. cingulata* appeared to be the species showing the highest relative abundance and frequency values.

Lithobiomorpha tended to show sex ratio values above one, while Geophilomorpha were below one. The sex ratio in Scolopendromorpha varied depending on the species, plot and sampling technique. However the significance of these values must be considered with caution due to the low number of individuals represented for some species.

Population densities

Figures 1–6 show monthly density values obtained using both sampling methods in each of the three study areas. Average density values for the whole sampling period are also shown. Based on these density values, two analyses have been performed. One of them tests whether significant differences existed between the average density values



Figs 1–6. Monthly densities of Chilopoda captured. 1. Through edaphic probes in riverside plot. Mean density ± standard error for the whole sampling period. 2. Through edaphic probes in rural plot. Mean density ± standard error of the whole sampling period. 3. Through edaphic probes in green oak forest plot. Mean density ± standard error of the whole sampling period. 4. Through direct capture in riverside plot. Mean density ± standard error of the whole sampling period. 5. Through direct capture in rural plot. Mean density ± standard error of the whole sampling period. 6. Through direct capture in green oak forest plot. Mean density ± standard error of the whole sampling period.

in each area using each sampling method. Paired t-tests revealed that very significant differences did appear between the chilopod density values in each plot, depending on the sampling method applied (riverside, $t=6.07$, $p<0.0001$; rural field, $t=4.2$, $p<0.01$; green oak forest, $t=4.93$, $p<0.001$). We concluded that, in order to evaluate centipede population densities in a study area, the use of soil samples and Berlese extraction is far more efficient than the direct capture technique.

The second analysis performed intended to test whether significant differences existed between the monthly density values of the communities in the three study areas. The Kruskal-Wallis test and STP (non-parametric multiple comparisons method) showed that the chilopod density values in the three habitats were not significantly different, whatever the sampling method used ($H=4.1$, $p=0.135$ for direct capture and $H=5.1$, $p=0.076$ for soil samples and Berlese extraction).

Table 8 shows the average density values and their variation coefficient, relative abundance and frequencies of each of the chilopod species occurring in each of the study habitats. Regarding the variation coefficients in the density values obtained through soil sampling, two types of distribution were observed. In some species, for example *L. borealis*, *G. insculptus* and *S. coleoptrata* in the riverside plot, the coefficients showed values well above 100. This suggests remarkable variation through the sampling cycle. In some other species like *L. lusitanus*, *P. ferrugineum* or *S. cingulata*, the coefficients below 100 indicate low variation of the average densities over time. For density values obtained by direct capture, the variation coefficients were high in all species, showing that the presence of Chilopoda under rocks was extremely variable during the year.

Significant differences existed between the densities of some species, depending on the sampling method used (Table 8). In some other cases, such as *L. calcaratus* in the riverside and rural plots, no such differences were noted.

Diversity

Tables 9–11 show species richness, diversity, maximum diversity, uniformity per month and average annual values of the centipedes captured using both sampling techniques in each of the three study habitats.

The species richness and average annual diversity values were highest in the riverside plot, followed by those in the rural plot and in the green oak forest. In the three habitats, the variation coefficients of all these indices obtained using soil sampling revealed low temporal variability. On the contrary, with the exception of the riverside habitat, the variation coefficients derived from the samples taken by direct capture indicated a highly heterogeneous distribution of the population indices.

Paired t-tests showed that there were significant differences between the average annual diversities depending on the sampling method used: riverside, $t=3.14$, $p<0.01$; rural field, $t=2.79$, $p<0.05$; green oak forest, $t=3.87$, $p<0.01$.

Variance analysis of monthly diversities in the three habitats using the Kruskal-Wallis non-parametric test revealed significant differences between the values obtained from soil sampling ($H=11.4$, $p<0.01$) and those obtained from direct captures ($H=7.17$, $p<0.05$) for the three habitats. The Student-Newman-Keuls multiple comparisons method showed significant differences ($p<0.05$) between the average diversity values of centipede populations from the riverside and green oak forest habitats, as well as between those of the rural field and green oak forest plots. The differences between populations from the rural field and riverside habitats are not statistically significant.

DISCUSSION

A study of the faunal composition showed differences between the three areas in question. The riverside plot appeared to support the highest species richness, with eight species being recorded. The average species richness (5 ± 0.52 and 2.92 ± 0.56, depending on the sampling method) also reached the highest values in the riverside plot. The most representative species in the riverside habitat according to the relative abundance and capture frequency were *L. lusitanus*, *S. cingulata*, *P. ferrugineum* and *L. castaneus*. It is noteworthy that *P. ferrugineum*, *G. insculptus* and *S. coleoptrata* were only captured in this plot. The number of species taken in the rural field habitat (seven) was slightly lower, and so was the average species richness (3.92 ± 0.57 and 2.31 ± 0.54). *Scolopendra cingulata*, *L. lusitanus*, *H. dimidiatus* and *S. canidens oraniensis* appear to be dominant species. The latter two species, together with *C. trisulcatus*, occured in this area only. Finally, the green oak forest supported the poorest chilopod fauna (three species), as well as the lowest average species richness (2.31 ± 0.26 and 1 ± 0.3), but *G. carpophagus* was unique to this habitat. *Scolopendra cingulata* was the only species appearing in all three study areas.

Considering the total number of chilopods, the analyses performed show no statistically significant differences between the monthly densities in the three habitats sampled.

The diversity and maximum diversity indices showed relatively low values in the three areas, regardless of the sampling method applied. The riverside community was the one presenting the highest average density (2.03 ± 0.21 and 1.28 ± 0.27), followed by the rural field population (1.69 ± 0.25 and 0.91 ± 0.27) and the green oak forest (1.08 ± 0.15 and 0.30 ± 0.16). Statistical analysis revealed statistically significant differences only between the monthly diversity values of the riverside and rural populations against the green oak forest one.

The riverside centipede community can be concluded to be the one presenting the highest species richness and diversity, followed by the rural field and green oak forest populations. The fact that no significant differences between the population densities were revealed could be due to the large monthly variation in all three study areas.

A comparison of results obtained from direct capture and from soil sampling and Berlese extraction, showed that the monthly density values of all Chilopoda were significantly higher for soil samples than those derived from direct capture. When considering the monthly densities of each species separately, the results are not the same. In some species such as S. *cingulata* and *L. lusitanus*, the differences in density values are very clear while in others those differences are insignificant. Nevertheless, we must consider that when converting the true number of individuals taken per study area to the number of individuals per square metre, the increase in the results obtained from soil samples is larger than in the results using direct capture. The differences between monthly diversity values show that soil sampling allows a better estimation of chilopod community structure.

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TABLE 1.

Sampling dates.

S1: 17-IV-1993
S2: 22-V-1993
S3: 19-VI-1993
S4: 16-VII-1993
S5: 21-VIII-1993
S6: 18-IX-1993
S7: 15-X-1993
S8: 20-XI-1993
S9: 18-XII-1993
S10: 22-I-1994
S11: 19-II-1994
S12: 19-III-1994
S13: 16-IV-1994

TABLE 2.

Chilopoda captured in the riverside plot using edaphic probes. Number of males (M) and females (F) captured; sex ratio (M/F); total number of individuals (T); frequency (Fr) and relative abundance (Ar) for each species.

Riverside	**M**	**F**	**M/F**	**T**	**Fr**	**Ar**
D. microcephalum	9	10	0.90	19	69.23	14.18
P. ferrugineum	8	14	0.57	22	84.61	16.42
G. insculptus	5	4	1.25	9	46.15	6.71
L. borealis	1	2	0.50	3	15.38	2.24
L. castaneus	9	6	1.50	15	46.15	11.19
L. lusitanus	19	10	1.90	29	100.00	21.64
S. cingulata	11	13	0.85	24	84.60	17.91
S. coleoptrata	8	5	1.60	13	53.85	9.70

TABLE 3.

Chilopoda captured in the rural field plot using edaphic probes. Number of males (M) and females (F) captured; sex ratio (M/F); total number of individuals (T); frequency (Fr) and relative abundance (Ar) for each species.

Rural field	**M**	**F**	**M/F**	**T**	**Fr**	**Ar**
H. dimidiatus	6	8	0.75	14	61.53	14.28
D. microcephalum	4	9	0.44	13	53.84	13.26
L. castaneus	7	3	2.33	10	46.15	10.20
L. lusitanus	13	10	1.30	23	69.23	23.46
S. cingulata	12	13	0.92	25	84.61	25.51
S. c. oraniensis	6	4	1.50	10	53.84	10.20
C. trisulcatus	0	3	_	3	23.07	3.06

TABLE 4.

Chilopoda captured in the green oak forest plot using edaphic probes. Number of males (M) and females (F) captured; sex ratio (M/F); total number of individuals (T); frequency (Fr) and relative abundance (Ar) for each species.

Green oak forest	**M**	**F**	**M/F**	**T**	**Fr**	**Ar**
G. carpophagus	9	13	0.69	22	69.23	29.73
L. borealis	10	8	1.25	18	69.23	24.32
S. cingulata	19	15	1.26	34	92.31	45.94

TABLE 5.

Chilopoda obtained through direct capture in the riverside plot. Number of males (M) and females (F) captured; sex ratio (M/F); total number of individuals (T); frequency (Fr) and relative abundance (Ar) for each species.

Riverside	**M**	**F**	**M/F**	**T**	**Fr**	**Ar**
D. microcephalum	4	5	0.80	9	46.15	16.98
P. ferrugineum	6	4	1.50	10	53.85	18.87
G. insculptus	3	0	–	3	23.07	5.66
L. borealis	0	1	–	1	7.69	1.88
L. castaneus	5	4	1.25	9	53.85	16.98
L. lusitanus	4	3	1,33	7	30.76	13.20
S. cingulata	5	6	0.83	11	84.61	20.75
S. coleoptrata	3	0	_	3	23.07	5.66

TABLE 6.

Chilopoda obtained through direct capture in the rural field plot. Number of males (M) and females (F) captured; sex ratio (M/F); total number of individuals (T); frequency (Fr) and relative abundance (Ar) for each species.

Rural plot	**M**	**F**	**M/F**	**T**	**Fr**	**Ar**
H. dimidiatus	5	6	0.83	11	38.46	23.40
D. microcephalum	0	3	1.50	5	30.76	10.63
L. castaneus	3	2	1.50	5	30.76	10.63
L. lusitanus	4	2	2.00	6	30.76	12.76
S. cingulata	5	7	0.71	12	53.84	25.53
S. c. oraniensis	5	3	1.66	8	38.46	17.02
C. trisulcatus	2	0	_	2	15.38	4.25

TABLE 7.

Chilopoda obtained through direct capture in the green oak forest plot. Number of males (M) and females (F) captured; sex ratio (M/F); total number of individuals (T); frequency (Fr) and relative abundance (Ar) for each species.

Green oak forest	**M**	**F**	**M/F**	**T**	**Fr**	**Ar**
G. carpophagus	3	5	0.60	8	38.46	38.09
L. borealis	2	2	1.00	4	23.07	19.05
S. cingulata	5	4	1.25	9	38.46	42.86

TABLE 8.

Average density (Dm) and variation coefficients (CV) for each one of the Chilopoda species obtained through edaphic probes and direct capture in the three habitats. The U-test shows the significance of the comparison between annual density distributions depending on the sampling method (ns = no significance; * p<0.05; ** p<0.01; *** p<0.001).

		Edaphic probe			**Direct capture**	
		Dm	**CV**	**U-test**	**Dm**	**CV**
Riverside	*D. microcephalum*	9.13	91.01	*	0.044	136.84
	P. ferrugineum	10.58	81.40	**	0.049	120.49
	G. insculptus	4.33	136.84	ns	0.015	190.03
	L. borealis	1.44	259.63	ns	0.005	360.56
	L. calcaratus	7.21	153.60	ns	0.044	108.49
	L. lusitanus	13.94	71.24	***	0.034	179.66
	S. cingulata	11.54	82.29	**	0.054	116.66
	S. coleoptrata	6.25	129.10	ns	0.015	190.03
	Total	64.42	59.46		0.260	81.02
Rural field	*H. dimidiatus*	6.73	116.61	*	0.054	158.90
	D. microcephalum	6.25	122.47	*	0.015	190.03
	L. calcaratus	4.81	131.66	ns	0.024	169.12
	L. lusitanus	11.06	108.61	*	0.029	168.19
	S. cingulata	12.02	77.89	**	0.059	120.81
	S. coleoptrata	4.81	120.49	ns	0.039	156.12
	C. trisulcatus	1.44	190.03	ns	0.010	244.10
	Total	47.12	85.90		0.230	103.21
Green oak forest	*G. carpophagus*	10.58	106.21	*	0.039	156.12
	L. borealis	8.65	91.06	**	0.020	204.89
	S. cingulata	16.35	74.11	***	0.044	170.75
	Total	35.58	73.27		0.103	137.35

TABLE 9.

Species richness (S), diversity (H), maximum diversity (Hmax) and uniformity (E) per month for the Chilopoda populations captured in the riverside plot.

	Edaphic probe				**Direct capture**			
	S	**H**	**Hmax**	**E**	**S**	**H**	**Hmax**	**E**
April	7	2.56	2.81	0.91	6	2.50	2.58	0.97
May	6	2.50	2.59	0.97	3	1.58	1.58	1.00
June	6	2.50	2.59	0.97	1	0.00	0.00	0.00
July	1	0.00	0.00	0.00	0	0.00	0.00	0.00
August	2	1.00	1.00	1.00	0	0.00	0.00	0.00
September	3	1.50	1.59	0.95	4	1.92	2.00	0.96
October	6	2.21	2.59	0.86	1	0.00	0.00	0.00
November	7	2.66	2.81	0.95	4	1.79	2.00	0.90
December	5	2.16	2.32	0.93	2	1.00	1.00	1.00
January	5	2.25	2.32	0.97	3	1.58	1.58	1.00
February	5	2.17	2.32	0.93	4	2.00	2.00	1.00
March	6	2.42	2.59	0.94	6	2.41	2.58	0.93
April	6	2.47	2.59	0.96	4	1.92	2.00	0.96
Mean	5	2.03	2.16	0.87	2.92	1.28	1.33	0.77

TABLE 10.

Species richness (S), diversity (H), maximum diversity (Hmax) and uniformity (E) per month for the Chilopoda populations captured in the rural field plot.

	Edaphic probe				**Direct capture**			
	S	**H**	**Hmax**	**E**	**S**	**H**	**Hmax**	**E**
April	5	2.06	2.32	0.88	4	1.90	2.00	0.96
May	5	2.24	2.32	0.96	1	0.00	0.00	0.00
June	5	2.25	2.32	0.97	1	0.00	0.00	0.00
July	1	0.00	0.00	0.00	0	0.00	0.00	0.00
August	0	0.00	0.00	0.00	0	0.00	0.00	0.00
September	2	1.00	1.00	1.00	2	1.00	1.00	1.00
October	3	1.50	1.58	0.95	1	0.00	0.00	0.00
November	3	1.37	1.58	0.86	2	0.81	1.00	0.81
December	3	1.58	1.58	1.00	4	2.00	2.00	1.00
January	6	2.55	2.58	0.99	5	2.15	2.00	0.93
February	6	2.52	2.58	0.98	1	0.00	0.00	0.00
March	6	2.35	2.58	0.91	3	1.40	1.58	0.89
April	6	2.53	2.58	0.98	6	2.52	2.58	0.98
Mean	3.92	1.69	1.77	0.81	2.31	0.91	0.94	0.51

TABLE 11.

Species richness (S), diversity (H), maximum diversity (Hmax) and uniformity (E) per month for the Chilopoda populations captured in the green oak plot.

	Edaphic probe				**Direct capture**			
	S	**H**	**Hmax**	**E**	**S**	**H**	**Hmax**	**E**
April	3	1.50	1.58	0.95	1	0.00	0.00	0.00
May	3	1.38	1.58	0.87	1	0.00	0.00	0.00
June	2	0.92	1.00	0.92	1	0.00	0.00	0.00
July	1	0.00	0.00	0.00	0	0.00	0.00	0.00
August	0	0.00	0.00	0.00	0	0.00	0.00	0.00
September	3	1.46	1.58	0.92	1	0.00	0.00	0.00
October	2	0.92	1.00	0.92	3	1.59	1.59	1.00
November	2	0.92	1.00	0.92	1	0.00	0.00	0.00
December	2	0.92	1.00	0.92	0	0.00	0.00	0.00
January	3	1.52	1.58	0.96	0	0.00	0.00	0.00
February	3	1.46	1.58	0.92	0	0.00	0.00	0.00
March	3	1.50	1.58	0.95	3	1.41	1.59	0.89
April	3	1.49	1.58	0.94	2	0.92	1.00	0.92
Mean	2.31	1.08	1.16	0.78	1	0.30	0.32	0.22